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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
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POSITIVE IONS IN THE MIDDLE ATMOSPHERE
DURING SUNRISE CONDITIONS

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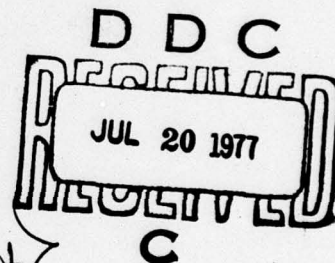
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White Sands Missile Range, New Mexico 88002

May 1977

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Two subsonic Gerdien condenser experiments were recently conducted at White Sands Missile Range, New Mexico, to study upper atmospheric ionization processes during morning twilight conditions. The same instrument was flown on 15 July 1975 at 0618 MST ($X = 75^\circ$) and 26 September 1975 at 0600 MST ($X = 90^\circ$). Electrical conductivity data from two subsonic blunt probe experiments (9 June 1971 at 0809 MST ($X = 53^\circ$) and 28 July 1971 at 0705 MST ($X = 68^\circ$)) are also included in this study. next page chi			

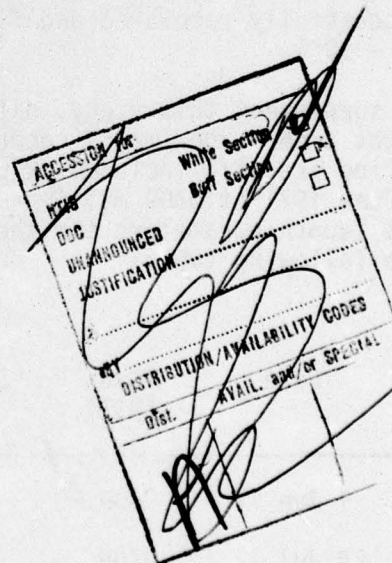
20. Abstract (cont)

cond → At 30 km, the positive ion conductivity data for the four flights are generally in good agreement, thus indicating no particular discrepancies due to differences in launch dates or measurement techniques. Above 60 km, the buildup in conductivity with respect to the launch times presumably reflects an increase in positive ion number density associated with solar ultraviolet ionization. The most noticeable buildup, however, occurs between 35 and 60 km where the positive ion conductivity values increase during the early morning period by as much as an order of magnitude (between 45 and 50 km). The Gerdien condenser measurements indicate that this buildup in conductivity is related to an increase in positive ion mobility, thus suggesting the presence during the early morning hours of a solar dependent process for forming smaller, more mobile positive ions.

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INTRODUCTION

Two subsonic Gerdien condenser experiments were recently conducted at White Sands Missile Range (WSMR), New Mexico (32° N, 106° W), to study ionization processes in the middle atmosphere during the morning twilight period. Previous studies [1] involving mid-latitude blunt probe electrical conductivity data obtained during the midday period have indicated day-to-day conductivity variations in some cases of a factor of two to three in the 30 to 60 km altitude region. A strong correlation was observed between positive ion conductivity (the electrical conductivity associated with positive ions) and temperature, particularly in the 48 to 58 km region where the temperature coefficient for this parameter was found to be typically $4\%/^{\circ}\text{K}$. These variations in conductivity are thought to be at least partly attributed to the dependence of ion mobility on temperature.

Since the ionization variability studies using blunt probes have primarily concentrated on the midday time period, it was decided to extend this research by considering the early morning period at a mid-latitude site. Gerdien condenser experiments, which have the advantage over blunt probe experiments of being able to measure charge number density and ion mobility in addition to electrical conductivity, were conducted on two mornings during 1975. The first Gerdien condenser was launched from WSMR on 15 July at 0618 MST ($\chi = 75^{\circ}$). The instrument was successfully recovered and flown again on 26 September at 0600 MST ($\chi = 90^{\circ}$).

To supplement this study, data obtained from two previous subsonic blunt probe experiments conducted at WSMR during the early morning period are also included [2]. These experiments were launched on 9 June 1971 at 0809 MST ($\chi = 53^{\circ}$) and 28 July 1971 at 0705 MST ($\chi = 68^{\circ}$). The launch parameters for these rocket experiments are summarized in the following table:

Date	Time (MST)	Solar Zenith Angle ($^{\circ}$)	Experiment	Apogee (km)
9 Jun 71	0809	53	Blunt Probe	79
28 Jul 71	0705	68	Blunt Probe	78
15 Jul 75	0618	75	Gerdien Condenser	69
26 Sep 75	0600	90	Gerdien Condenser	75

THE GERDIEN CONDENSER EXPERIMENT

The Gerdien condenser is an instrument capable of measuring electrical conductivity, charge number density and ion mobility [3,4]. Recent rocket experiments utilizing this technique either subsonically or supersonically have been reported by Rose and Widdel [5]; Conley [6]; Farrokh [7]; Croskey [8]; and Widdel, Rose, and Borchers [9]. The particular Gerdien condenser used in this research was flown on a stabilized parachute system after separation at apogee from a rocket. Figure 1 shows a picture of the instrument.

The inner electrode of the condenser, which was recessed to reduce possible fringing effects, was used as the collecting electrode and had a length of 6.35 cm and a radius of 1.11 cm. The radius of the outer return electrode was 3.81 cm. The voltage applied to the collector was swept over a range from approximately -5 to +5 V.

DATA

Positive Ion Conductivity

Positive ion conductivity profiles for the four rocket experiments discussed previously (above table) are given in Figure 2. The general agreement between the conductivity profiles at 30 km suggests that no appreciable variations resulted from either differences in launch dates or measurement techniques. Between 45 and 55 km, the positive ion conductivity values are observed to progressively increase as the solar zenith angle decreases, with an overall enhancement of an order of magnitude observed in the 45 to 50 km altitude region. Possibly, some of these conductivity variations are attributed to the differences in launch dates; however, an order of magnitude change is much greater than that typically associated with either day-to-day variations [1] or variations with respect to solar activity [10]. Also, the temperature variations associated with the launch dates are not sufficient to explain the changes in conductivity.

The positive ion conductivity profile for 9 June 1971 ($\chi = 53^\circ$) is indicative of the mid-latitude, midday blunt probe conductivity values between 30 and 60 km [1], and thus the early morning buildup in this altitude region would presumably diminish for solar zenith angles considerably less than 53° .

The three conductivity profiles for $\chi = 75^\circ$, 68° , and 53° show a rather well-defined knee in the region above 55 km, indicating the altitude above which ionization by solar ultraviolet radiation is considered to be an important production mechanism for positive ions [2]. The differences in positive ion conductivity above 60 km, particularly evident in the profiles for $\chi = 68^\circ$ and 53° , are probably associated with differences in solar ultraviolet ionization.

Ion Mobility

Figure 3 shows ion mobility data for the two Gerdien condenser experiments. On 26 September at least two distinct groups of positive ion mobilities were observed in the 50 to 60 km altitude region, as are indicated by the shaded and light circles. The shaded circles represent the mobility values for the less mobile positive ions. The positive ion mobility values for both days tend to fall off with decreasing height and have an altitude dependence which is approximately inversely proportional to that for neutral number density. The positive ion mobility values for 15 July ($\chi = 75^\circ$) are generally larger than the corresponding values for 26 September ($\chi = 90^\circ$), particularly below 50 km where there is typically a factor of two difference. Telemetry dropout was experienced on the 15 July flight, thus limiting the number of ion mobility measurements and making it difficult to determine if additional smaller ion mobility groups were present.

In the 40 to 45 km altitude region, the positive ion mobility values for both flights were observed to noticeably shift to the left with decreasing altitude. Since the ion mobility values below 45 km were too small to be measured by the 26 September Gerdien condenser experiment, the dashed line has been constructed to show the limit of the instrument's sensitivity as an upper limit for the positive ion mobility values in that region. A similar shift in positive ion mobility was observed previously on a subsonic Gerdien condenser flight reported by Rose and Widdel [5].

Ion Number Density

Figure 4 shows the positive ion number density measurements for the two subsonic Gerdien condenser experiments. The light and shaded circles are again associated with the more and less mobile ions, respectively, measured on 26 September. For the cases between 50 and 60 km in which different ion mobility groups were observed, the concentration of less mobile positive ions was consistently greater than the corresponding number density of more mobile ions. The total concentration of positive ions in the 45 to 65 km altitude region for both days was on the order of 10^2 cm^{-3} , with no discernible trend evident as to which of the 2 days had the higher total number densities. Below 45 km, the comparatively larger ion number density values for 15 July are associated with the less mobile ions observed in that altitude region.

DISCUSSION

In the 45 to 55 km altitude region, where the principal source for positive ions is due to ionization by galactic cosmic rays, the positive ion conductivity profiles (Figure 2) appear to be displaying a solar dependence. This is further demonstrated in Figure 5 where the secant

of the solar zenith angle is plotted as a function of positive ion conductivity. The number of data points is limited by the number of experiments; however, linear relationships are indicated at 50 and 55 km for the data at solar zenith angles of 53°, 68°, and 75°. The data for $\chi = 90^\circ$ would obviously not fit these linear relationships, and previous blunt probe data obtained later in the morning (1050 MST, 13 October 1971 [$\chi = 44^\circ$]) did not fit well either. Thus, from what data are available, the solar dependence of positive ion conductivity appears to be an early morning phenomenon.

Combining the Gerdien condenser positive ion conductivity data with the ion mobility (Figure 3) and charge number density (Figure 4) measurements for 15 July ($\chi = 75^\circ$) and 26 September ($\chi = 90^\circ$) shows that the increase in conductivity corresponding to a change in solar zenith angle from 90° to 75° is principally associated with an increase in ion mobility. Such behavior could be explained by a process involving photodissociation of larger positive ions into smaller, more mobile ions. Further evidence demonstrating such behavior has been observed in Croskey's [8] recent Gerdien condenser measurements in which enhancements in positive ion conductivity resulting from a Lyman- α ionization source were found to be directly attributed to enhancements in ion mobility.

The precursory ions for such a process could possibly be cluster ions with mobilities so small that they were undetected by the Gerdien condenser. The existence of such large ions, possibly in the form of charged ice particulates, has been considered in the analysis of previous blunt probe data by Chesworth and Hale [11]. If this were the case, the mobilities of these ions would probably be even somewhat smaller than those previously reported by Rose and Widdel [5] and Farrokh [7]. The presence of such relatively immobile ions would also help reconcile the somewhat lower number density values measured in these experiments with the Gerdien condenser ion number density data reported by other experimenters [5-9].

CONCLUSIONS

In summary, evidence has been presented to suggest that positive ion conductivity during sunrise conditions at mid-latitudes is a solar dependent parameter in the altitude region above 30 km. Appreciable conductivity variations with respect to solar zenith angle were observed in the region where ionization by solar ultraviolet radiation is not considered to be relatively significant. Subsonic Gerdien condenser and blunt probe experiments measured as much as an order of magnitude increase in ion conductivity at some altitudes (45 to 50 km) over a change in solar zenith angle from 90° to 53°. Ion mobility data from the Gerdien condenser experiments indicated that the increase in ion conductivity primarily resulted from an increase in ion mobility, thus suggesting the presence of a photodissociation process for positive ions during the early morning period which results in smaller, more mobile ions.

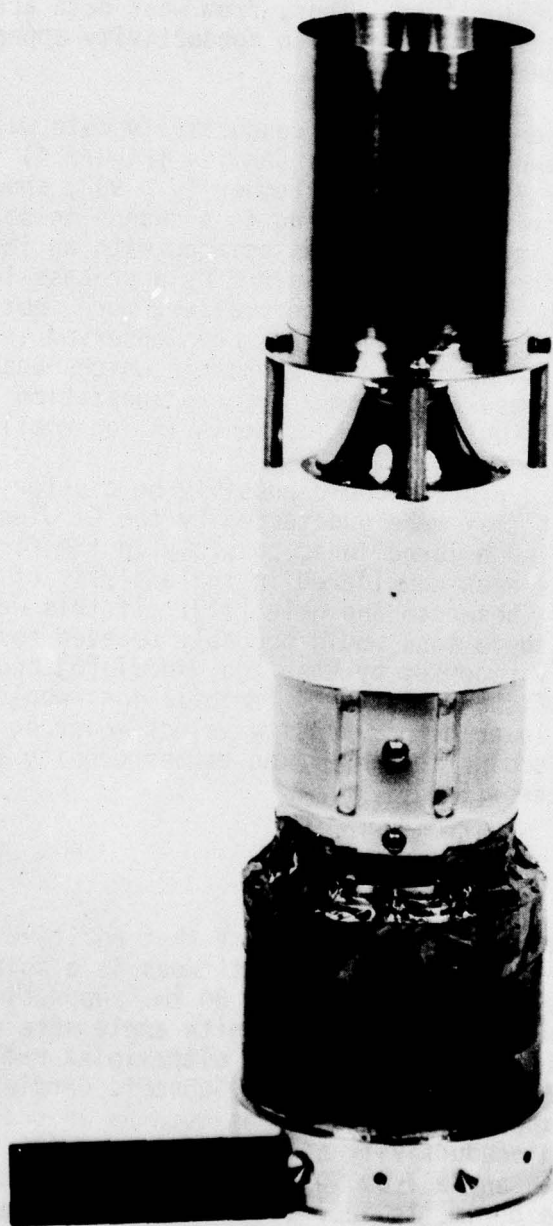


Figure 1. Gerdien condenser payload.

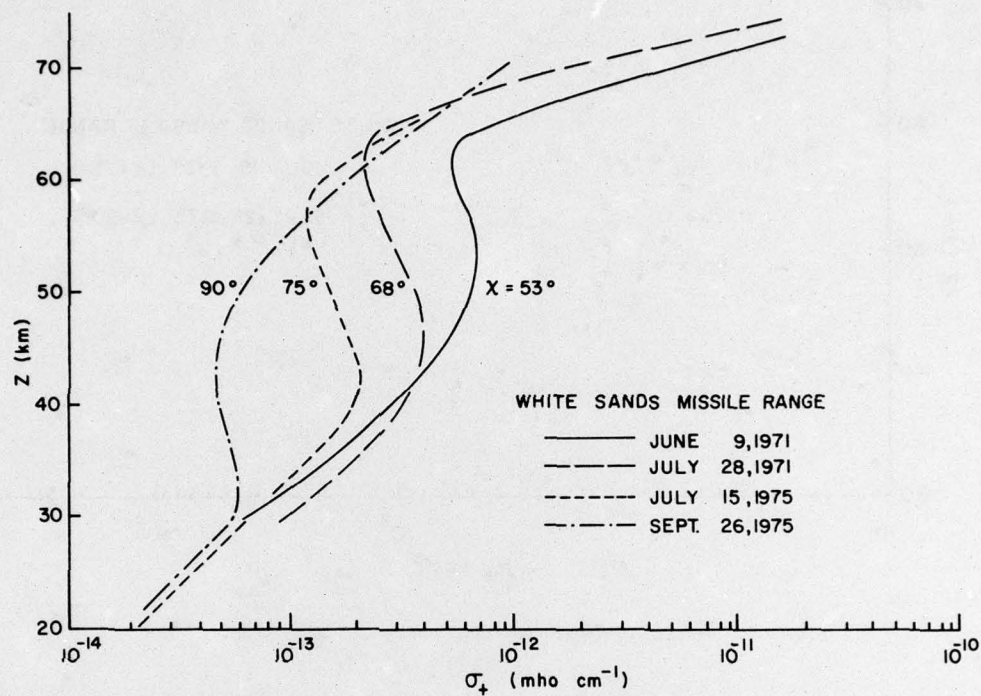


Figure 2. Positive ion conductivity profiles for WSMR morning rocket launches.

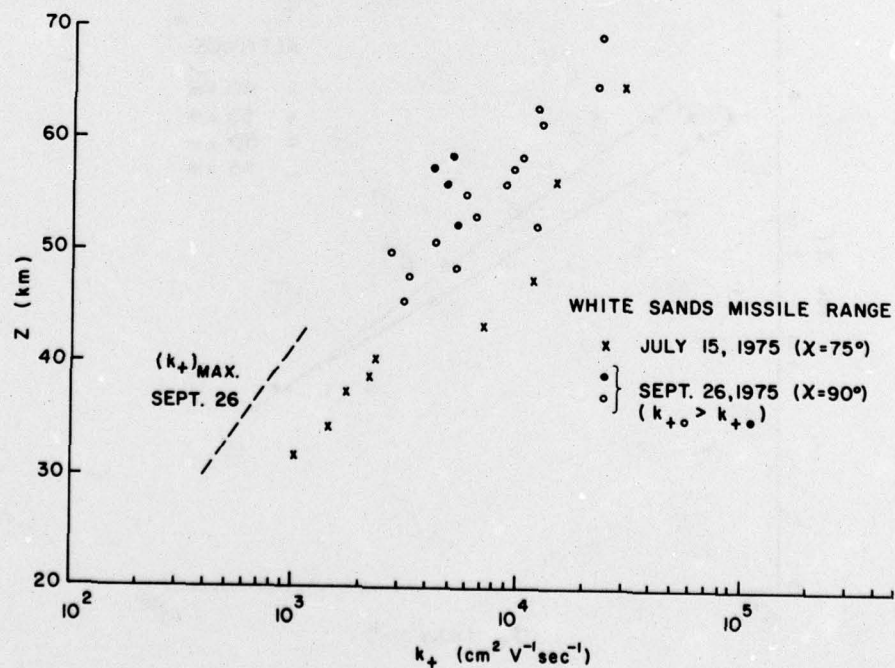


Figure 3. Gerdien condenser positive ion mobility data.

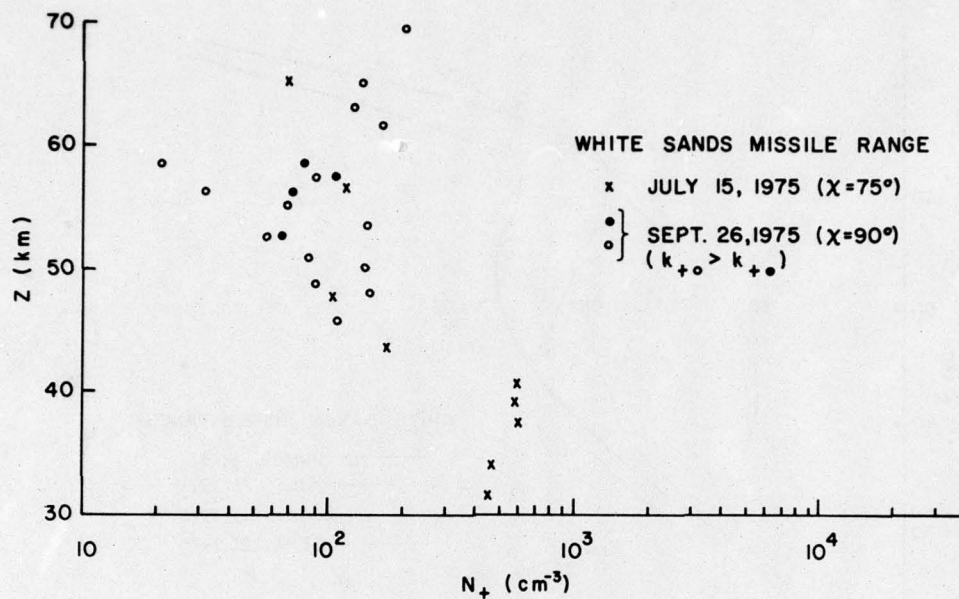


Figure 4. Gerdien condenser positive ion number density data.

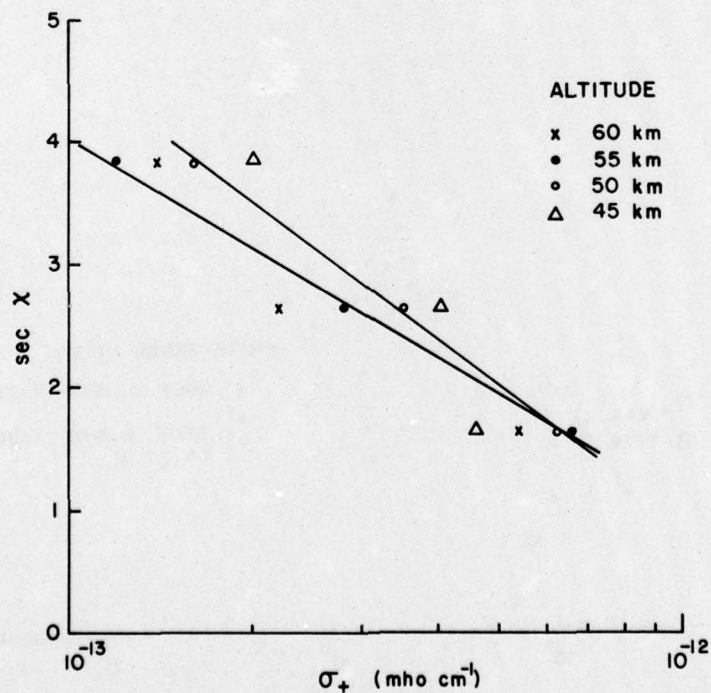


Figure 5. Solar dependence of WSMR morning positive ion conductivity values.

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